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METHOD AND COST OF QUARRYING, CRUSHING, AND GRINDING LIMESTONE AT THE CATSKILL PLANT OF THE NORTH AMERICAN CEMENT CORPORATION, CATSKILL, N. Y.

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BY

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METHOD AND COST OF QUARRYING, CRUSHING AND GRINDING LIMESTONE AT THE CATSKILL PLANT OF THE NORTH AMERICAN CEMENT CORPORATION, CATSKILL, N. Y.[1]

By W. J. Fullerton[2] and Albert W. Cox[3]

INTRODUCTION

This paper is one of a series being prepared by the U. S. Bureau of Mines describing mining and milling methods and costs at cement-plant quarries throughout the United States, and deals directly with methods and costs at the quarry and mill of the North American Cement Corporation at Catskill, N. Y. The process of manufacturing cement is described only as far as the final grinding of the raw materials.

These papers are designed to disseminate technical information regarding the methods used. The cost tabulations represent local operating expenditures only and not total production costs. It is recognized that publication of total production costs may in many instances cause embarrassment to individual producers, as well as to the industry as a whole. On the other hand, operating costs are essential to the technical discussion and study of methods employed. The attention of the reader is specifically called to this differentiation in order that no misunderstanding of the scope of the cost tabulations may ensue.

The authors wish to acknowledge the assistance of the following persons who helped in the collection of information: R. W. Jones, mining engineer of Catskill, N. Y.; G. A. Witte, assistant general manager; H. F. Kichline, chief chemist; and C. A. Hartman, quarry foreman.

HISTORY

The first prospecting on the property was done in 1914 and 1915, and quarrying operations were started in February, 1916. During the early operation of the quarry, drilling was done by tripod drills and all stone was loaded by hand. Transition to the modern methods of quarrying, to be described subsequently, was made gradually.

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[1] - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6522."

[2] - One of the consulting engineers, U. S. Bureau of Mines, and enginoer of the North American Cement Corporation.

[3] - One of the consulting engineers, U. S. Bureau of Mines, and experimental engineer of the North American Cement Corporation.

GEOLOGY

The Devonian beds in which the quarrying operations are conducted are folded into a series of anticlines and synclines, with the folds strongly developed along a general north-south strike. Another series of folds has an east-west strike, but is not so pronounced. The formations are disturbed by a series of overthrusts, rather closely spaced and having an easterly dip. The overburden varies from 0 to 5 feet in thickness and consists of glacial sand and clay deposits with a small amount of siliceous material from the Oriskany.

The limestone is of the following designations: Esopus, Alsen, Becraft, New Scotland, and Coeymans. The Becraft beds are high in calcium carbonate, and quarrying operations are conducted largely in them, with the method of quarrying determined by their position. Figure 1 shows an elevation of the quarry with the limits of the present working face.

The vertically dipping Becraft stone at the east end of the quarry is difficult to drill due to seams, faults, and an occasional small cave. Toward the west, where the dip is not so steep, drilling is less difficult, although the greater hardness of the New Scotland stone underlying the Becraft at the western end of the quarry slows up drilling. About one hole out of ten is lost, due to broken drills, seams causing the drill to lose direction, etc. Most of the trouble is encountered in the vertically folded stone at the east end of the quarry.

PROSPECTING AND SAMPLING

As stated, the first prospecting on the property was done in 1914. Holes were put down with a shot drill and the core samples obtained were analyzed by R. W. Hunt & Co. of New York.

Prospecting for the second (North) quarry was done in 1920. In this instance well drills were used and sludge samples taken at every 4 feet of depth. The holes were spaced about 30 feet apart across the rock fold and 100 feet apart along the fold, and varied in depth from 60 to 100 feet.

Prospecting for the present (South) quarry was started April 17, 1925, and is still being carried on at intervals when drilled reserves require extension. Thus far, 85 well-drill holes ranging from 60 to 110 feet deep have been sunk. The spacing of these holes is irregular and was made to suit the known approximate strike of the rock folds. As a general thing the position of holes was restricted to points where the Becraft limestone was not exposed or where there was doubt about the grade of rock underlying the surface. Samples of drill-muds are taken at 5 foot intervals and are analyzed for calcium-carbonate content, with complete analyses when considered necessary.

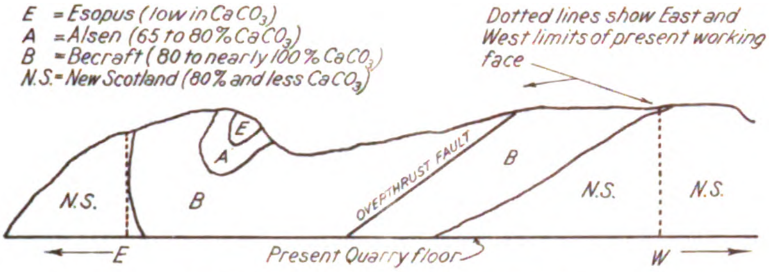
E = Esopus (low in $CaCO_3$)
A = Alsen (65 to 80% $CaCO_3$)
B = Becraft (80 to nearly 100% $CaCO_3$)
N.S. = New Scotland (80% and less $CaCO_3$)
Dotted lines show East and West limits of present working face
E
A
N.S.
B
OVERTHRUST FAULT
B
N.S.
N.S.
E
Present Quarry floor
W

Figure 1.- Elevation of quarry, looking south

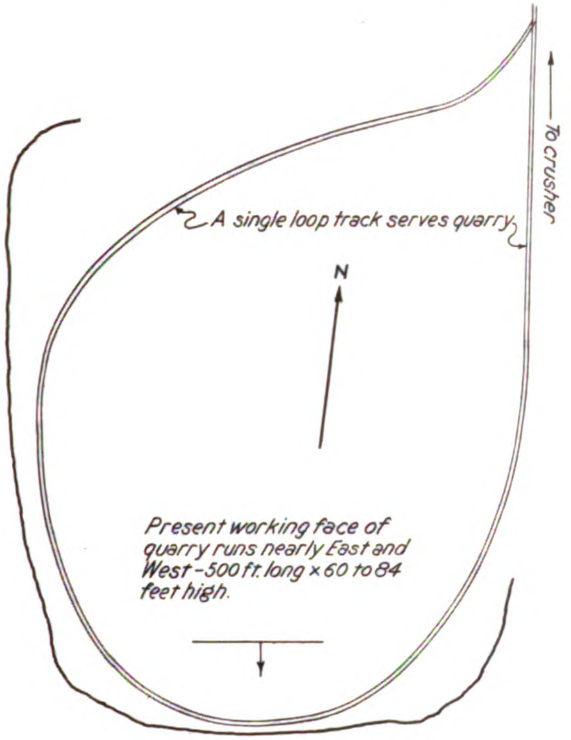
To crusher
A single loop track serves quarry
N
Present working face of quarry runs nearly East and West - 500 ft. long × 60 to 84 feet high.

Figure 2.- Plan of quarry and track

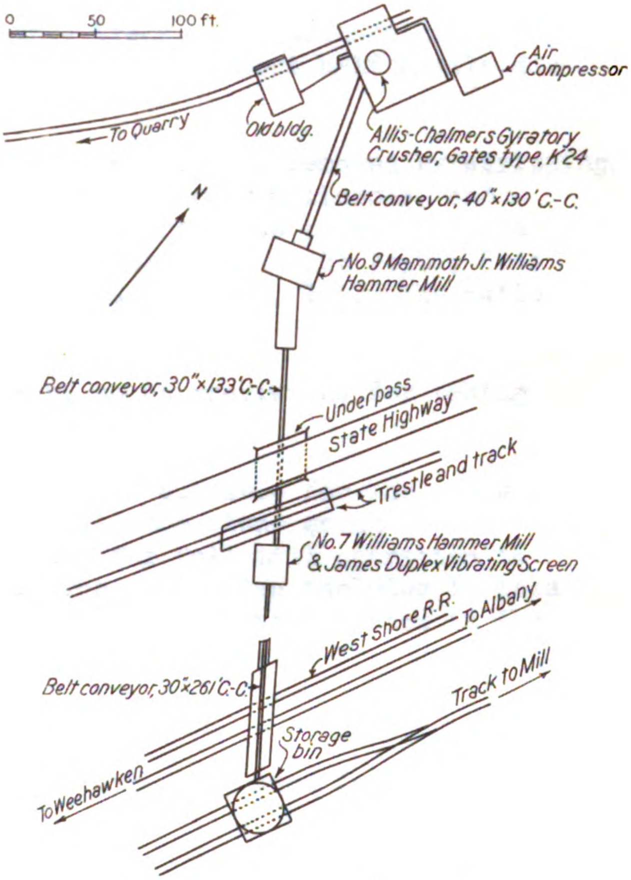
0
50
100 ft.
Air Compressor
To Quarry
Old bldg.
Allis-Chalmers Gyratory Crusher, Gates type, K 24
N
Belt conveyor, 40" × 130' C.-C.
No. 9 Mammoth Jr. Williams Hammer Mill
Belt conveyor, 30" × 133' C.-C.
Under pass
State Highway
Trestle and track
No. 7 Williams Hammer Mill & James Duplex Vibrating Screen
West Shore R.R.
To Albany
Belt conveyor, 30" × 261' C.-C.
Track to Mill
Storage bin
To Weehawken

Figure 3.- Layout of crushing plant

Prospecting is done when convenient as a matter of routine and is kept about 400 feet in advance of the quarry face.

After major jobs of prospecting, estimates of reserves are made by plotting the holes to scale on cross-section paper, and considering dip, average thickness, and length of formations, and calculating the contents of the proved ground in cubic yards. The tonnage is figured by assuming a weight of 125 pounds per cubic foot. For convenience, the stone is considered to be of two grades; one containing 80 to 100 per cent of $CaCO_3$, and the other from 60 to 80 per cent of $CaCO_3$.

QUARRYING METHODS

Figure 2 shows a plan of the quarry and track. The quarry face is approximately normal to the strike of the folding. The present working face runs nearly east and west, and is about 500 feet long by 60 to 84 feet high. The quarry is served by a single-loop standard-gage track. The primary crusher is situated approximately north of the working face and about half a mile distant.

The light overburden, varying from 0 to 5 feet, is not removed by stripping, but is shot down and handled with the stone. It is highly siliceous, and silica is a necessary component for the cement mixture. The percentage composition of the overburden is as follows: CaO, 5.5; SiO_2, 59.8; Fe_2O_3, 6.4; Al_2O_3, 14.3; MgO, 2.9; loss on ignition, 10.0; undetermined, 1.1. The ratio of overburden to stone is about 1 to 50 by weight.

There is natural drainage from the quarry, so no provisions for taking care of water are required.

Quarrying operations are confined to materials suitable for the cement mixture, so there is no waste from the quarry, all the stone going to the mill. The output varies from 1,500 tons per day for full mill operation to 1,000 tons per day for restricted operation. The overburden included in this output is about 2 per cent of the total tonnage. The quarry operates in the daylight hours only and averages about 10-1/2 hours a day.

Drilling

Three Loomis "Clipper" drills, of traction type, are used for primary drilling. A description of them follows:

1 No. 4ET, type AVE, powered by a 15-hp. electric induction motor;

1 No. 4ET, type AVE, powered by an 11-hp. electric induction motor;

1 No. 4GT, type JS, powered by an 18-hp. Cook gasoline engine.

The electric drills are liked best because they are easily started in cold weather and because it is not necessary to haul gasoline and water to them. But since it is inconvenient to operate them at points far from the electric power lines, the gasoline drill is used for prospecting. Comparative figures for operating costs of the different drills are not available, but the following figures of performance during 1930 should be interesting:

Comparison of drill performance, 1930

Drill	Total feet drilled	Hours operated	Feet per hour
15-hp. electric	5762	1592	3.62
11-hp. electric	3927	1514	2.59
18.hp. gasoline	2806	1119	2.51
Total	12495	4225	Average 2.96

The bits used with the drills are of the Gill type, and vary in diameter from 5-1/2 inches for the smallest to 6-1/4 inches for the largest; they are all about 4 feet long. The holes drilled are about 6 inches in diameter and extend to a point 6 or 8 feet below the quarry floor. The holes for primary blasting are spaced about 30 feet back from the quarry face and 16 to 18 feet apart. The spacing is controlled by the required fragmentation, the height of face, and the hardness of rock. The present practice in spacing holes was developed by experimenting over a period of about 18 months, during which time six primary blasts were set off. Distances between holes ranging from 16 to 22 feet and distances from face to holes ranging from 20 to 32 feet were tried, one set of measurements being used for one blast so that there was no chance for confusion through using several different spacings in one blast. After calculating the tonnage shot down against the fragmentation and ease of cleaning up the shots, the present spacings were adopted as standard.

A 7-inch iron pipe 6 or 7 feet long is used to case through the light overburden during drilling.

Secondary drilling for breaking bowlders is done by jackhammer drills, using 7/8-inch hexagon bits, varying in length from 2 to 14 feet. Compressed air having a pressure of 70 pounds per square inch is used.

Blasting

Twenty or more holes are loaded for each primary blast. A crew of 10 men handles the routine of loading, which is about as follows: 3 men truck dynamite from the magazine to a position near the holes, 3 men carry dynamite and earth for tamping to the holes, and 4 men load the holes. It takes about one-half hour to load each hole.

No springing of holes is done. Where the rock is hard and solid the hole may be completely filled with dynamite, but for less solid rock the dynamite is alternated with 5 or 6 feet of dirt, so placed that the dirt plugs in adjoining holes will be at different levels. At the bottom of every second hole and in all holes at the end of the straight section of the working face, where it curves from an east-west direction toward a north-south direction, 100 pounds of 75 per cent quarry gelatin is used. Clay is used for tamping in summer, and stone screenings in winter.

No. 6 Hercules exploders, with plain and covered cordeau, detonate the primary blasts. No. 6 Hercules exploders are used for secondary blasts.

The following tabulation shows the quality and quantity of dynamite used in 1930.

Total stone quarried in 1930	281,400 short tons

Dynamite used for primary blasting (sticks 5 x 16 or 24 in.):

	Pounds
75 per cent quarry gelatin	11,250
60 per cent quarry gelatin	30,850
60 per cent Red Cross	37,800
60 per cent Gelex A	9,050
Total	88,950

Stone blasted per pound dynamite	3.16 tons
Dynamite used for secondary blasting (sticks 1 x 8 inches) (Extra D)	9,450 pounds
Stone blasted per pound dynamite (secondary)	29.78 tons
Dynamite used for both primary and secondary blasting	98,400 pounds
Stone blasted per pound dynamite	2.86 tons

The track along the working face and for a safe distance back along the line toward the crusher is removed before setting off primary blasts. The whole quarry force is employed in removing the tracks and replacing them later. The shovel loads the rails and the bundles of ties slung together with chain, onto the quarry cars, which are moved away to a safe distance. Following the blast and after the shovel has cleaned up the loose stone, the track is replaced.

Loading

The steam shovel is a 100-B, full-circle, caterpillar-type Bucyrus with a 3-yard dipper. It loads the stone into 12-yard Western side-dump cars which are hauled by an 18-ton Vulcan steam locomotive to the primary crusher. The shovel crew consists of one operator, one fireman, and one pitman. The one shovel handles the quarry output of 1,000 to 1,500 tons per day. The steam shovel is being replaced by a Marion electric shovel, type 4160, mounted on crawling traction trucks, equipped with 34-foot steel boom, 21½-foot dipper stick and 4-cubic yard dipper, and operated by 2,300-volt, 3-phase, 60-cycle alternating current. The steam shovel is to be transferred to another quarry of the company, where the tonnage handled is somewhat less.

A shovel of the electric type was deemed desirable for several reasons, the principal ones being cheaper operation and the ease of bringing power to the shovel and keeping the shovel in repair. The electric shovel has a 4-yard dipper, as compared with a 3-yard dipper on the shovel it is replacing. Power will be brought to the shovel by a No. 4 four-conductor Rome super-service cable, 750 feet long.

Upon arrival at the primary crusher, the loaded cars are dumped by means of a compressed-air cylinder, which hooks and lifts one side of the car, dumping the stone into the crusher. The layout of the crushing plant (not including grinding mills) is shown in Figure 3.

Transportation

The track in the quarry is laid directly on the quarry floor and is not ballasted. The men who do the secondary drilling and blasting also maintain the track. Little work is required for routine maintenance, probably only a few man-hours in a month.

Although the plan of the quarry (fig. 2) shows the quarry track as a loop, the full loop is not used at present. The locomotive approaches the shovel with empties from the east and removes these cars to the east after they are loaded. After the removal of the four loaded cars from the shovel, the locomotive must take them to the crusher and pick up empties to serve the shovel, hence the shovel is idle for about 10 minutes while waiting for the empties.

In present practice the locomotive is always on the crusher side of the loads at the shovel, but at the run-around switch at the crusher it shunts them by and getting on the shovel side of the loads, pushes them beyond the crusher, and picks up a train of four empties. The locomotive is then between the loaded cars and the empties, and starting for the shovel with the empties on the shovel side, drops the loaded cars at the crusher where a car puller operated by compressed air places the cars for dumping.

The loop track will be placed in use within a few weeks. The locomotive will then handle trains in cars of three, approaching the shovel from opposite sides alternately, and pushing a train of loads away as it places a train of empties. In this way there will be no lost time at the shovel. Three trains of three cars each will be used, and while a train is in transit, there will be a train at the shovel and another at the crusher. This change in practice will involve no changes in track layout other than some grading on the storage track beyond the crusher, so that empties can be dropped down for the locomotive.

In moving the track serving the working face, the track is taken apart in sections about 150 feet long, and the shovel lifts the track to its new position. It makes the first move of the track from its position on the quarry-face side of the track, then moves through the opening between the sections of track to the outside of the track. The work is completed from the outside, except that an opening large enough for the shovel to pass is left, and this is closed after the shovel is again between the track and face.

Crushing and Screening

The 1,500 tons of stone (plus overburden) quarried per day passes successively through a gyratory crusher, a large hammer mill, and a small hammer mill. About 150 tons of clay is added at this point and passes through the ball mills and the tube mills with the stone, each of the two ball mills handling about half the total tonnage and each of the four tube mills handling about one-quarter of it. There is no sizing during the process, except that a screen with 5/8-inch openings removes about one-third of the discharge of the large hammer mill as undersize which by-passes the small hammer mill. However, upon completion of the new screen equipment the stone-clay-water slurry will be screened at the ball mills.

The machines used for crushing and grinding, with the approximate size of reduction and the rate of output for each, are listed below. The output figures for slurry are based on weights of dry material, and do not include the weight of water.

Machines used for crushing and grinding, showing approximate size of reduction and rate of output for each

Machines	Size of material		Output, tons per machine per hour
	Entering	Leaving	
1 No. 24 Gates-type gyratory crusher	4 feet and under	8 inches and under	[1]104
1 No. 9 Williams hammer mill	8 inches and under	1 1/2 inches and under	[1]104
1 No. 7 Williams hammer mill	1 1/2 inches and under	5/8 inch and under	[2]70
2 Allis-Chalmers ball mills, 8 ft. diam. 7 ft. long (preliminators)	5/8 inch and under	94 per cent passing 10-mesh sieve	[3]31.9
4 Allis-Chalmers tube mills, 7 ft. diam. by 16 and 20 ft. long	97 per cent passing 10-mesh sieve	90 per cent passing 200-mesh sieve	[3]15.4

Per cent passing:	No. 7 hammper-mill discharge = ball-mill feed	Ball-mill discharge = tube-mill feed
200 mesh	--	51.0
100 "	11.1	55.8
80 "	12.5	57.4
60 "	14.2	59.4
50 "	16.4	62.2
40 "	20.1	66.4
30 "	24.2	71.2
20 "	41.2	79.4
10 "	47.0	93.8
6 "	63.5	--
4 "	--	100.0
3/8 "	88.5	--
3/4 "	100.0	--

1 - Approximate average output in 1930; figures do not represent capacity of machines, but average output.

2 - Estimated average output; about one-third the material by-passes this mill through the screen.

3 - Average output in 1930.

Note: The gyratory crusher and the two hammer mills crush stone (plus overburden); the two ball mills and four tube mills grind slurry (stone-clay-water). The output figures for these grinding mills are based on weights of stone and clay without water; the proportion of stone to clay is about 9 to 1.

The output figures for the ball mills and tube mills are based on the mill hours operated and tons ground for the year 1930. The outputs per hour for these mills are not comparable to those for the gyratory crusher and hammer mills for the reason that the grinding mills operate day and night, as needed to maintain stocks of ground material for the kilns, whereas the crusher and hammer mills operate in the day only. The slack is taken up by the concrete stone storage bin after No. 7 hammer mill, by the open storage served by a Whiting electric crane, and by the preliminator (ball mill) feed bins. There is no storage between the ball mills and the tube mills, so the tube mills must operate when the ball mills operate. The operating ratio is usually two tube mills to one ball mill, but sometimes with one ball mill running, three tube mills are run in order to maintain the fineness of hard grinding material. This will account for the slight discrepancy between the total of 61.6 tons per hour for the four tube mills and the 63.8 tons for the two ball mills.

The gyratory crusher is a Gates-type Allis-Chalmers crusher, model K-24, and is driven through a belt by a 200-hp. induction motor. The larger hammer mill is a No. 9 Williams Mammoth Jr., and is driven at 870 r.p.m. by a direct-connected 500-hp. slip-ring motor.

The smaller hammer mill is a No. 7 Williams New Type and is driven at 1170 r.p.m. through a direct drive by a 200-hp. slip-ring motor. This mill is preceded by a 2-deck James Duplex vibrating screen, with screens 4 feet wide and 7 feet long. The upper deck is for heavy screening and scalping, and the lower deck for producing the finished product. The stone passing through the lower deck is about one-third of the total tonnage handled by the screen, so that the material retained on the screens and going from them to the hammer mill is about two-thirds of the total tonnage. The stone leaving the small hammer mill and that passing through the screen is carried away by a belt conveyor.

Grinding

The following table gives operating data for the grinding mills during 1930 when 312,700 tons of slurry (not including weight of water) was ground.

Operating data for grinding mills, 1930

	Ball mills	Tube mills
Approximate ball load, pounds	24,000	50,000
Diameter of balls, inches	4	7/8
Total weight of balls, worn out, pounds		319,305
Total cost of balls		$13,922
Weight of balls worn out per ton of ore ground, pounds		1.021
Cost of balls per ton of ore ground		$0.0445
Cost of replaced liners	$281.00	$4,701.00
Cost of replaced liners per ton of ore ground	$0.0009	$0.0150

No ball consumption is shown for the ball mills. There was an unknown quantity of old balls used, balls that were not carried on the stores card and which were thus not charged to the ball mills when used. Hence there is no way of computing the consumption.

The cost figures represent the cost of the balls and liners only and do not include labor. Ten end liner plates, and no side liners, were put in the ball mills. Seventeen end liner plates and two complete sets of liner plates were put in the tube mills.

The two ball mills are Allis-Chalmers preliminators, 8 feet in diameter by 7 feet long. One mill has been equipped with a rotary trommel screen, the oversize from which passes to an elevator to be returned to the mill. This trommel screen will be removed, however, as two 8-foot, type 42 "Hum-mer" screens are being installed to serve the two preliminators. As mentioned before, clay and water are added to the stone as it enters the preliminators, and the "Hum-mer" screens will handle this slurry. The slurry passing through the screens will go directly to the tube mills, while the oversize will be returned to the preliminators for further grinding. Each preliminator is driven at 20 r.p.m. through a countershaft, pinion and gear, by a 200-hp. synchronous motor.

The four tube mills are of Allis-Chalmers make, 7 feet in diameter; two are 16 feet long and two are 20 feet long. Each tube mill is driven at 21.8 r.p.m. through a countershaft, pinion and gear, by a 300-hp. induction motor.

As stated, grinding of the stone with clay is done to reduce and mix the materials preparatory to burning to cement clinker. Although no grading for sizes is done, close control of the fineness of the slurry leaving the tube mills is effected by means of sieve tests made at hourly intervals. Coarse particles are detrimental to easy and complete combination of the components during burning. The fineness of the slurry leaving the tube mills is regulated by controlling the rate of their feed. The fineness of the slurry is kept at or above 90 per cent passing a 200-mesh sieve.

The chemical composition of the raw material is kept under strict control. Samples of the slurry leaving the tube mills are analyzed hourly for their calcium-carbonate content. Chemical control of materials extends from the quarry through the various plant departments, but it is not necessary to describe it here. The proper composition of the raw materials is attained by the following controls:

Quarrying stone that is suited for the cement mixture.
Blending of crushed stone in the open storage.
Use of proper amounts of clay, varying the quantity to suit composition requirements.
Blending of slurry in tanks by mechanical and air agitation.

The material-handling equipment and practice are summarized as follows:

From	Means of transportation	To
Quarry face	One 18-ton Vulcan steam locomotive, 4-wheel, saddle-tank, hauls quarried stone about 1/2 mile in 12-yard, Western, side-dump cars in trains of four cars over standard-gage track; rails, 60 pounds per yard; maximum grade, about 1 per cent	Gyratory crusher.
Gyratory crusher	One belt conveyor, with belt 40 inches wide and 130 feet between centers, conveys crushed stone	No. 9 hammer mill.
No. 9 hammer mill	One belt conveyor, with belt 30 inches wide and 133 feet between centers, conveys crushed stone	No. 7 hammer mill.
No. 7 hammer mill	One belt conveyor, with belt 30 inches wide and 261 feet between centers, conveys crushed stone	Concrete stone storage bin.
Concrete stone storage bin	One 40-ton Porter steam locomotive, 4-wheel, saddle-tank, hauls crushed stone about 4,000 feet in 40-ton steel hopper cars in trains of two cars over standard-gage track; rails, 67 and 80 pounds per yard; maximum grade, about 2 per cent	Open storage.
Open storage	One Whiting electric crane, 3 yard capacity, span 80 feet, powered by four motors, handles stone in storage and reclaims it from storage (this crane also serves cement-clinker and coal storages). It delivers to one 24-inch by 153-foot belt conveyor, which in turn delivers to the 20-inch by 220-foot belt conveyor that delivers to the ball-mill feed bins	Ball mills (preliminators).

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From	Means of transportation	To
Clay quarry	One 40-ton Porter steam locomotive (used also for hauling stone) hauls clay about 1,500 feet in 6-yard, Western, side-dump cars in trains of three cars over standard-gage track; rails 67 and 80 pounds per yard; maximum grade about 2 per cent.	American clay machine.

Note: Water is added to clay in the clay machine and the clay in suspension is pumped to storage tanks by a centrifugal pump. It runs by gravity, as needed, to the two ball mills, where it meets the stone and where more water is added. The slurry consists of about 57 per cent of stone, 5 per cent of clay, and 38 per cent of water.

Ball mills (preliminators)	Two Link-Belt chain-and-bucket elevators, with 8 by 8 by 16 inch buckets, receive the slurry (stone-clay-water) from the trough leading from the two ball mills, and deliver it to a 40-foot Smidth horizontal mechanical agitator which feeds it to the four tube mills	Tube mills.

The electric power used by the motors is 3-phase, 60-cycle, 440-volt alternating current. The air compressor serving the quarry is a 750 cubic foot Chicago Pneumatic machine driven by a 130-hp. synchronous motor.

QUARRYING AND HANDLING CLAY

Clay-quarrying operations are simple, and a few words will suffice to describe them. Clay is used as a source of silica, iron, and alumina for the cement mix. The clay is soft and plastic with no sandy material and but little loam. One 3/4-yard full-revolving, caterpillar-type, Osgood steam shovel is used. The dipper noses into the clay bank and tears out the material which it loads into 6-yard, Western, side-dump cars. The clay is hauled by steam locomotive to the 10-foot American clay machine, where water is added and the clay broken. The suspended clay is pumped to storage tanks, whence it runs by gravity to the preliminators, as needed.

SAFETY AND FIRST-AID WORK

In discussing the subject of safety and first-aid work it is difficult to separate safety activities in the quarry from those of the plant as a whole, but the following statements are applicable to the quarry in that it is one department of the cement plant.

There is a plant safety committee, made up of all plant department heads, which meets monthly to discuss safety and first-aid matters. There is another group known as Distinguished Safety Workers Club, made up of 12 workmen who have shown outstanding interest in safety work. This group meets monthly and is presided over by the chairman of the plant safety committee. Each second Saturday a departmental safety meeting is held, at which a workman gives a talk on safety and dangerous and unsafe practices are discussed and suggestions made for their elimination. A good-housekeeping campaign, with regular inspections, is carried on in all plant departments.

Some time ago a first-aid instructor from the U. S. Bureau of Mines visited the plant and trained selected men in first aid, and the bureau first-aid methods are used at the quarry and throughout the plant. The men first trained in this work have in turn acted as instructors for other men of the plant organization, until now 40 of the 150 men employed at the plant have had first-aid training. There are two first-aid teams in the plant, made up of the men most proficient in this work, and it is planned to have these teams compete.

QUARRY ORGANIZATION AND SCALE OF WAGES

A list of men employed at the quarry will suffice to indicate the quarry organization and includes the following:

1 quarry foreman
3 well drillers
1 shovel operator
1 shovel fireman
1 shovel pitman
1 blaster
1 locomotive engineer
1 gyratory-crusher operator
1 jackhammer driller
1 hammer-mill operator (for 2 mills)
1 conveyor-belt operator
1 blacksmith
1 blacksmith's helper
2 car repairmen
1 night watchman

The total quarry force, including employees of the crushing department but not those of the grinding department or clay quarry, is 18 men. The foreman is paid a monthly salary and the workmen are paid on an hour basis, their rates of pay varying from 40 cents to 73 cents, with an average of 53 cents an hour. There is no contract or bonus system used. The quarry normally is operated 10-1/2 hours a day, in daylight only, and about 270 days a year. The quarry is usually closed on Sunday and there is a shutdown of some weeks during the winter.

COSTS

The costs of quarrying stone, crushing stone, quarrying clay, and grinding stone plus clay given in the following table are based on operations for the full year 1930.

Quarry costs for dry stone. Year of 1930; stone quarried, 281,400 tons

	Per ton
All labor	$0.0988
Supplies other than power, fuel, and explosives	.0394
Electric power	.0061
Coal (shovel and locomotive)	.0166
Explosives	.0499
Stripping	0
Total cost	$0.2108

Cost of crushing dry stone (before addition of clay) in gyratory crusher and two hammer mills. Year of 1930; stone crushed, 281,400 tons

	Per ton
All labor	$0.0371
Supplies other than power and fuel	.0436
Electric power	.0178
Coal for locomotive hauling	.0047
Total cost	$0.1032

Cost of quarrying clay. Year of 1930; clay quarried, 31,300 tons.

	Per ton
All labor	$0.0835
Supplies other than power and coal	.0118
Coal for shovel and locomotive	.0178
Total cost	$0.1131

Cost of grinding slurry (stone plus clay). Year of 1930; material ground, 312,700 tons.

	Per ton
All labor	$0.0613
Supplies other than power	.0797
Electric power	.1398
Total cost	$0.2808

Labor for grinding includes wages of clay-machine operator, belt-conveyor operator, etc.

Man-hours per unit of production. Year 1930; stone, 281,400 tons; clay, 31,300 tons.

Quarry: Man-hours per ton of stone quarried.	0.169
Crushing: Man-hours per ton of stone crushed	.073
Clay: Man-hours per ton of clay quarried ...	.168